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THREE DIFFERENT MODES OF TEETHING AMONG SELACHIANS.*

BY PROFESSOR LOUIS AGASSIZ.

About two years ago Mr. Orestes St. John came to the Museum of Comparative Zoology with a very large collection of fossil fish teeth, with the intention of identifying them and comparing them with those which we had in our own collections. This became an occasion for me to look over the materials we possess. In former years I had paid considerable attention to the subject and contributed somewhat to the advancement of our knowledge in respect to the peculiarities of teeth among the representatives of the class of Selachians. I soon found that the progress of paleontology and zoology made the present materials on hand quite insufficient for the task. It was not known how constant the characters derived from the teeth among Selachians could be considered to be, or, with few exceptions, what changes took place with age. So I determined upon the voyage of the Hassler

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*This paper is printed from a report taken of Professor Agassiz' communication before the "National Academy of Sciences" at its meeting in Cambridge, Nov. 20, 1872. It was the intention of the author to revise the report for publication in the NATURALIST, and he had begun to do so, the first four pages of the manuscript having been corrected during the last two weeks that he was at his museum. The paper can therefore be considered in part as one of the latest efforts of the lamented author, and it must be remembered that he would undoubtedly have made many additions and some changes, had not his fatal sickness taken him from the very midst of his active labors.—Eds.

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to make the collecting of Selachians a principal object of my attention, and to gather specimens in greater number than is usually the case with animals of these large dimensions. I have been richly rewarded for my efforts though it has been at the cost of considerable labor. We now possess in the Museum many thousand specimens of Selachians. I do not suppose there is another collection covering so largely the different stages of growth of these animals. I have examined these specimens one by one and since my return have made a very careful examination of one species in several families, in order to have standards of comparison based upon the study of several hundred specimens for each family.

The result of this examination shows that while in their adult condition the Selachians present characters which are very constant among specimens of the same age, such marked changes take place among them during their growth that even genera have been founded on the difference of age. I wish to show first, that among the adults we have constancy of character. As an example I may take a species of Odontaspis of which I have twenty-five adult specimens. I have selected this genus for special study on account of its relations to the fossil species of the tertiary formation. In Odontaspis the front teeth are placed as if there were a set of front teeth distinct from the canine teeth, and back of them molar teeth of a very different size, all the specimens exhibiting the same arrangement and even the same number of teeth. This is generally the case with the sharks proper. But when we compare specimens of different ages we find in that respect a great deal of difference. There are some species in which at an early age the adult condition is already established, and where the changes are only in the size of the teeth. There are other genera, on the contrary, in which the young have fewer rows, and rows of different kinds of teeth from those which are developed at a later day. As to the manner in which the changes take place I have noticed three essentially different modes of teething.

One is the ordinary mode of development of the teeth among sharks, in which there is a row of teeth standing erect along the outer margin of the jaws, and behind them as many rows of teeth reclining backwards as there are erect teeth outside. These reclining teeth are in various stages of growth ; so that to the erect teeth functionally used in catching the prey there correspond three, four, five, six or seven immature teeth placed one behind the other in the fold of the gum, the youngest occupying the innermost portion. These teeth come into play one after another as the front teeth drop off. This is the mode of teething among Selachians with which all zoologists are familiar, as it occurs among sharks generally and among our common skates. The jaw of our large barn-door skate, *Raja ocellata*, for instance, exhibits vertical rows of teeth placed one behind the other, as in the sharks, the innermost of which are immature, while those along the outer edge of the jaw are ready to drop. Some of these teeth may be so slightly attached to the gum that they drop readily, while others are so connected with the jaw that they serve their purpose for a longer time. Now in Selachians which have this mode of teething the teeth begin to show themselves rather late in life. The embryos of these sharks and skates do not have teeth, and even after birth the young show very imperfect or rudimentary teeth. In some of them, after being for some time in the water and providing for their own food, the teeth are so imperfectly developed that no row is visible along the edge of the jaw; but when the teeth rise to the margin of the jaw their number is already fixed and the young teeth are formed in rows behind those of the outer series. From that time no other change takes place except that larger and larger teeth are formed behind the old ones as these drop in succession; and as the old ones drop the next oldest come into play and so on.

In Galeocerdo, a genus of much interest to paleontologists, the teeth are very uniform in both jaws and more nearly of the same size than in other families, while the teeth which are to replace the old ones are not much larger, thus showing that these sharks grow very slowly. These facts are very important with reference to the identification of the fossil species. In younger specimens of this genus there are fewer rows of replacement teeth and they resemble adult teeth much less than they do here. As the jaw enlarges with age, the new sets of teeth enlarge also, and in that manner the whole margin is always occupied by teeth.

In Cestracion, on the contrary (and under this name I designate the Port Jackson shark and not the hammer-heads), we have a totally different mode of teething, the knowledge of which is essential to a correct appreciation of the zoological value of a vast number of fossil teeth characteristic of the older and middle geological formations. I have been fortunate enough to secure a large number of specimens of the Cestracion living along the coasts of California, Peru and the Galapagos Islands. I have those of Australia also in various stages of growth, so that I could ascertain the mode of dentition of the genus by a comparison of different species. In the adult, as is well known, the front teeth are pointed, while the lateral teeth are grinders, and there are grinders with flat surfaces and grinders of different forms, in the middle of the jaw and behind. What is particularly characteristic of these fishes is that the teeth rest upon the surface of the jaw, forming flat expanses for chewing, and that many teeth are at work at the same time; also that the inner part only of the rows is in progress of formation, while a great many rows act at the same time.

In this condition, the genus Cestracion has been described, and it is generally understood that what distinguishes it is the presence of these different kinds of teeth; but when I had an opportunity to examine the younger ones, I found that there were none of those peculiar teeth in the back part of the jaw. Young that swim about in search of prey exhibit only the conical teeth at the anterior part of the jaw and have none of the teeth with flat surfaces at the hinder part of the jaw. What is still more striking is that these front teeth, corresponding to the front teeth of the adult, have not single points as in the adult but two lateral prongs. The teeth which are behind are gradually reduced to three prongs, and finally only one prong with a little hook on the side, and in very old specimens even these little prongs at the side are wanting; so that you have a succession of different teeth resulting from the gradual change in the teeth of the same series. The first teeth of the young have this complicated character which is maintained through successive droppings before the teeth of another character come in. These remain for a time again until a third type of teeth is brought in. As these changes go on in the front we find that row after row is added behind, so that the number of rows covering the surface of the jaw is gradually increased.

We see in this a different arrangement from the other sharks, in which the total number of teeth in the jaw is early established and remains the same for life, while here the number of rows increases and the rows forming behind have a totally different character from those in front. The front teeth in these rows constantly drop and give place to others. This implies a functional differentiation which is marvellous. Mark that every tooth that replaces another has a different character from the previous one. We have here opportunities for variation, for changes, for transmutation, to an extent which has not been noticed in any other family of animals as far as I know.

Let me here say that from single specimens of Cestracions, obtained in different parts of the world, have been indicated three supposed genera based on the conditions of the teeth at different periods of age.

To show that this should not be accepted as an unquestionable result, let me say that I have examined the young of the three supposed genera. They are all provided with keeled molar teeth, while the adults have the flat grinders supposed to be characteristic of the Cestracion type alone. I am therefore satisfied that it is worth while to collect largely and preserve a number of specimens, even if they be sharks and skates and occupy a great deal of room, in order to learn their history, which has shown of just what importance has been the identification of teeth among fossils. Thus sharks drop their teeth and scatter them along the bed of the ocean in great numbers, probably ten or twenty times as many as they have at one time while living, so that it is not to be wondered at that we so frequently find in collections of fossils loose teeth of sharks, and that we so rarely find the jaws of sharks with teeth in their places.

Of course in those species in which the teeth are isolated and do not support one another, we should hardly ever expect to find them fossil in position; while those which are pressed upon one another may be found in the fossil state, and that occurs again and again, and among the fossil fishes there are a number of sharks in which jaws with teeth arranged in rows are represented.

There is a third mode of teething as different from the other two as these two are different from one another. It occurs in the family of Myliobatidæ among the skates. In Myliobatis, as generally known in the mature condition, we have a middle row of broad and short teeth; along the margin are a number of rows of smaller teeth, and it is known that in front these teeth drop and are replaced from behind. For a long time I could not understand how teeth of a large size could follow the teeth of very small dimensions which exist in the young. In the teeth of the young taken from the mother, embryos therefore, and not young in the ordinary sense, the whole width of the dentary portion of the jaw is not half the width of the central tooth of an adult, but on careful examination it will be seen that the hind part of these teeth is not as broad as the front part. They form in fact cones, and of course a cone long enough will bring to the front part very small teeth. Teeth as small as a pin's head are actually found in the jaw. I have examined a number of jaws of Myliobatis, all of which show that fifty times as many teeth must have been dropped as remain in the jaw. The teeth are not pushed sidewise: they are pushed forward. This occurs in Myliobatis, where we have a number of teeth varying from a single one in the centre of the jaw, to four rows on each side and a middle row in addition, all of which progress from behind forward. In the genus Ætobatis the teeth are conical, the front part being much narrower than the hind part.

The introduction of the new kind of teeth is a complicated thing to explain, and to state the changes which they undergo by age would occupy too much time. Let me say only, that besides these principal modes of teething we have some modifications of them which are characteristic of particular families. In the ordinary skates (Raja) the rows of teeth are disconnected from one another and run from the margin inward in unbroken continuity. In the sting-rays (Trygon) and all the representatives of that family, they cover the jaw closely and are quincuncially arranged. That is, while in the common skates the rows are nearly straight, in the sting-rays there are border rows and between them other rows, so that the whole surface of the jaw is covered with teeth. It is as if the teeth of the common skate had been brought together and crowded, so that one row was pressed into the space of another; the teeth do not drop singly but are brought forward like a pavement, the margin of which is gradually dropping.

There is another modification characteristic of the dog-fish (Acanthias) in which the teeth of the successive rows overlap one another from the side; not uniformly from both sides but from one side; so that one tooth overlaps the other tooth, and so on, as if they had been squeezed from the side and made to pass over the next tooth in that way.

If from the living sharks we pass to the fossils, we have still other modes of teething. We find in some of them instead of distinct teeth plates covering the jaw, only three plates on each half of each jaw. These plates are conical; that is, pointed along the margin and broader inward. The teeth increase by curving the point over the jaw while the inner margin is gradually enlarging. The triangular pointing of the teeth accounts for the increased dimensions of the teeth from the young to the adult.

We have one further step where the teeth, instead of being only laid down on the surface of the jaw, are actually incorporated with it, so soldered with it that between the jaw and teeth there is hardly any difference recognizable.

THE WILD CATTLE OF SCOTLAND, OR WHITE FOREST BREED.

BY E. LEWIS STURTEVANT.

According to our best authorities two forms of the ox tribe, the genus Bos, existed in Scotland at an early period, *Bos primigenius* and *B. longifrons* of Owen. The former was of large size, and according to all accounts the color was black; it had white horns with long black points, the hide was covered with hair shorter and smoother than in the tame ox, but on the forehead long and curly. From the skeletons preserved in our museums the length of this gigantic ox must have been from eleven and one-half to twelve feet, and the height at the shoulders about six or six and one-half feet.* Darwin remarks that the Pembroke race in England closely resembles this ox in essential structure, and that the cattle at present existing in the Chillingham Park are degenerate descendants of this breed.† *Bos longifrons*, on the contrary, is described as a distinct species, of small size, short body and fine legs. It was domesticated in England during the Roman period.‡ Professor Owen thinks it probable that the Welsh and Highland cattle were descended from this species.§

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* Nilsson, Annals and Mag. of Nat. Hist., 1849, iv, 258.

† Animals and Plants under Domestication, i, 103.

‡ British Pleistocene Mammalia, p. xv.

§ Animals and Plants under Dom., i, 104.